9th APSEC
JOINT CONFERENCE 2015
8th ACEC
civil.utm.my/apsec2015

UTM UNIVERSITI TEKNOLOGI MALAYSIA | Faculty of Civil Engineering

AUN/SEED-Net JICA

Proceedings of the

9th Asia Pacific Structural Engineering and Construction Conference (APSEC 2015)
& 8th Asean Civil Engineering Conference (ACEC 2015)

CD version

3-5 November 2015

Menara Razak
Universiti Teknologi Malaysia Kuala Lumpur
(UTMKL) Malaysia

EDITOR-IN-CHIEF

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"Sustaining the world with better structures and construction practice"

Proceedings of the
9th Asia Pacific Structural Engineering and Construction Conference (APSEC 2015) and
8th Asean Civil Engineering Conference (ACEC 2015)
Sustaining the World with Better Structures and Construction Practice
CD version

Published by
Faculty of Civil Engineering
Universiti Teknologi Malaysia
81310 Johor Bahru,
Johor, MALAYSIA.

Perpustakaan Negara Malaysia Catalaguing-in-Publication Data
Printed in Malaysia

eISBN 978-983-44826-8-8

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The Design of Geographic Information System (GIS) Prototype for Optimizing Road Infrastructure Performance

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Keywords: Road performance; GIS; Google-Maps API.

Abstract. Road infrastructure management requires very detailed information to carry out its main function to realize excellent road infrastructures in order to support the mobility of people and goods. Geographical Information Systems (GIS) have been used extensively to manage this information. This study aimed to design a GIS prototype based on open source services to provide information about roads in West Sumatera, Indonesia. Google-Maps API application used to provide those information. Ten main roads in Padang City chosen as a model with consideration to represent the functions of roads in West Sumatera. By utilizing secondary data from relevant road authority and process it with coding and integration with the Google-Maps, this study has managed to design the GIS prototype. This information will be useful as a guideline for the stakeholders in the road infrastructure in West Sumatera as well as Padang City to take appropriate action in order to optimize the road performances.

Introduction

Development in the field of transport infrastructure is one of the basic industries of the national economy. It is the support and the guarantee for the development of economy and society [1]. Among the infrastructure facilities that contribute significantly to the economic and social life of a country is the roads [2]. At present, road infrastructure performance management system emphasizes the importance of sustainability to optimize the road function in support of mobilization and transport of people and goods [3]. The issue of sustainability is becoming increasingly discussed as life plan-based road infrastructure management is considered ineffective because it does not consider the performance of the road so that the potential to cause various problems in different conditions [4]. In fact, the planning of maintenance as part of the road infrastructure management does not always correspond with the actual conditions at the time of execution. Budget availability is usually not sufficient to guarantee the performance of road has always been at a level that assured during the life of the plan [5].

Various different approaches have been proposed to measure and assess the road performance as an alternative method for the of life plan-based management, which have a number of disadvantages. The use of key performance indicators (KPI) and Critical Success Factors (CSF) in implementing the performance management is one of the proposed [2]. A study conducted to formulate a model of maintenance of road infrastructure in Padang City based on the importance of its handling [6]. The model uses a number of criteria that assessed road with integration of Screening System Fuzzy-AHP approach. Another study modeling the computerized life cycle financing for road infrastructure in Padang City [7]. Financing models in Padang City roads graded can not accommodate road damages due to road construction only oriented to start-up costs such as the construction cost without considering future costs and short road life plan. The study concludes that the life cycle cost approach can solve this problem and produce optimal cost in the road infrastructure management.

Later, the utilization of information technology becomes widely discussed topic in an effort to optimize the transport sector performances, including road infrastructure. Road infrastructure management requires very detailed information, such as road network, road layout and others [8]. Geographic Information Systems (GIS) has been known as one of the applications of information technology that is used comprehensively for managing spatial data in large volumes [9, 10]. In the road infrastructure area, GIS has been widely used, especially in developed countries [11]. GIS is a tool that has the potential to support the information management, especially useful for infrastructure managers attempt to develop better transport network for the general public [12]. Later, the information management related to important factors and assessment in the road maintenance and management has been made possible with the use of GIS [13, 14]. GIS are widely applied in the field of road infrastructure, particularly for road maintenance and rehabilitation [15, 16, 17], pavement management system (PMS) [18, 19, 20] and traffic management and accident [21].

There are various kinds of software are available for GIS applications. The use of commercial software products requires a license and needs to be renewed every year. As a result, users need to spend any amount of money for this purpose. Therefore, the use of open source software (Web-GIS) was proposed as a way to overcome it in developing a road management system [11]. This study aimed to design a GIS prototype based on open source services to provide information about roads in West Sumatera. This information is a requirement for any stakeholders related to road infrastructure, both providers and users. Provision of accurate and comprehensive information to be able to realize the optimum road infrastructure performances in order to support the movement of people and goods.

Methodology

The main objective of this research is to build a GIS prototype by using the toolkit developed by Google for mapping services, namely Google Maps Application Programming Interface (Google-Maps API). This toolkit is used because of its superiority in easy access to hundreds of web applications based on Google-Map through a web browser with an internet connection [22]. Google-Maps API is very useful in the creation of the GIS, where digital maps for these systems has been provided by Google so it does not need to create a digital map. Thus, the work can be focused on the data and information that will be displayed by the GIS. Using the Google-Maps API to work on GIS provides several advantages following: a simple maps storage system, it can be accessed anywhere with an internet connection, we do not need to create a new map, the map data changes more quickly and this system will be lighter [23].

GIS prototype in this study was designed to modelling the main roads in West Sumatera are represented by the ten main roads in Padang City. Those tenth roads were chosen as a model with consideration to represent the function of the roads in West Sumatera, mainly because of high traffic flow and road capacity [2].

GIS prototype design methodology with Google-Maps API in this study are described in the following steps:

1. Road attribute data collection to be processed into information on the GIS prototype.
   The data used in this study is secondary data obtained from the two road authorities in Padang City, the Department of Public Works Department of Padang City and Road Infrastructure, Spatial and Settlement Agency of West Sumatera.
2. Making the road routes on Google-Maps.
   Making the road routes on Google-Maps performed by utilizing the web pages developed by Google, which is at the following address:
   https://developers.google.com/maps/documentation/utilities/polylineutility
3. The encoding for each road section.
   To make road routes, first set some latitude and longitude coordinates on the roads in the provided map window. Some coordinates will then be connected into a line that can represent the roads on the map. After the line is obtained, then the application will automatically

generate a unique code that can be seen in the Encoded Polyline and Encoded Levels column. This unique code that will be used in application development.

4. Integrating the code into the Google-Maps.
   By utilizing php-javascript, then the code is inserted into the array variable and displayed on a map on Google-Maps. When a map is displayed, the selected type of map is satellite view by defining it on the code:
   "mapTypeId: google.maps.MapTypeId.SATELLITE".

Result and Discussion

Ten main roads in Padang City and their attributes are identified based on secondary data from the relevant authorities, as shown in Table 1. Administration status of these tenth roads belong to the city streets, where its presence is enabled to support community mobilization and goods in Padang City. Based on its function, approximately 50% is the primary arterial roads, 40% serves as secondary arterial roads and only 10% are roads with a secondary local function. Almost all these roads are built by using the hotmix asphalt pavement construction and approximately 90% of its surface condition is in good condition. Based on data from the Directorate General of Land Transportation, Ministry of Transport, Republic of Indonesia in 2013, only 49.08% of the total roads in Padang City is equipped with sidewalks and 80.09% are equipped with road markings [24]. This indicates that the roads in Padang City has not been fully equipped with road.

Encoding of each road section then performed to form lines representing determined roads. The code is unique for each road section. The coding is shown in Table 2 and one of the encoding results are shown in Figure 1.

Table 1: The main roads in Padang City and their attributes

Road Names	Attributes										
	Subdistrict	Length (m)	Width (m)	Administration Status	Segment Classification	Surface Pavement Type	Surface Condition	Drainage Availability	Drainage Status	Roadside Availability	Roadside Condition
Indarung Street	Lubuk Kilangan	14083	10	CS	PA	HA	G (100%)	N/A	-	N/A	-
Teluk Bayur Street	South Padang	2069	20	CS	PA	HA & RA	G (70%), SD (30%)	A (100%)	OD	N/A	-
By Pass Street	Kuranji & Koto Tangah	25715	10	CS	SA	HA	G (100%)	A (48,56%), N/A (51,44%)	OD	A (51,44%)	Construction: Gravel, Width: 2m
Sudirman Street	West Padang	1557	14	CS	PA	HA	G (100%)	A (100%)	CD	N/A	-
Khatib Sulaiman Street	North Padang	5213	22	CS	PA	HA	G (100%)	A (100%)	CD	N/A	-
Prof. Dr. Hamka Street	North Padang & Koto Tangah	7212	25	CS	SA (95,85%), PA (2,40%), SL (1,75%)	HA	G (100%)	A (4,15%), N/A (95,85%)	CD	A (95,85%), N/A (4,15%)	Construction: Cement, Width: 1,5 m
Adinegoro Street	Koto Tangah	16606	4	CS	PA	HA	G (75%), SD (25%)	A (100%)	OD	A	Construction: Ground, Width:1 m
Gajah Mada Street	Nanggalo	3367	10	CS	SA	HA	G (100%)	A (100%)	OD	A	Width: 2 m
S. Parman Street	North Padang	2918	15	CS	SA	HA	G (100%)	A (100%)	OD	N/A	-
Pemuda Street	West Padang	1214	4	CS	SL	HA	G (100%)	A (100%)	CD	N/A	-

Remarks:

CS	= City Street	HA	= Hotmix Asphalt	A	= Available
PA	= Primary Artery	RA	= Readymix Asphalt	N/A	= Not Available
SA	= Secondary Artery	G	= Good	CD	= Closed Drainage
SL	= Secondary Local	SD	= Slightly Damaged	OD	= Opened Drainage

Table 2: The encoding for each roads section

No	Road Names	Encoded Polyline
1	Indarung Street	p|yD}~xcRcCuJgDsTcCqGaC{ImGc`@_Cg[uAaR{Gq`@}CiRG{KcBcHC{B~ByLr@{FGkM?kFv@eEvSgc@TwCUsByAkFHs@xC{BrHqC`CcBhBkA~BiEdAaEr@cG`@oB~@uCQuB_G}XuF}XyAoSa@{BuAsDwD_F
2	Teluk Bayur Street	t|yD}~xcRbSqFfDm@jDUbCXvBv@|DfCzp@nq@~BhBfDtAdKlAlPJrI`@xGX`CpAdD`EjXxh@FtE`BxCfOpH
3	By Pass Street	t|yDy~xcR_[nHsUvD_SjB_d@jBac@tC}x@bEsXhAcQl@yJCeKKkSUoJj@}SpCm]dFaXtAqd@tAqN~AqIlDcOfIkUdMkKjHykFbuDeIbHyGvMcDxNeBv_@kD`OePxUa|DvpBiKfCiRtAaKj@mEvBkD|EeAvE_CxR
4	Sudirman Street	tnuDaypcR|Z@b`@uD|WoD
5	Khatib Sulaiman Street	d}oDayncR`@cDh~@km@jSkKph@a@
6	Prof. Dr. Hamka Street	|ciD_smcRza@gQlj@cP~c@iGvc@_BhNbDjOlElIr@`KmClIQ
7	Adinegoro Street	fwyCqxgcRhYwBjb@uAbe@fCvJiDjp@{h@~y@e_@tHhC~k@?hRuH|dE}aB
8	Gajah Mada Street	btsD{`rcRcVzGuKlD}F~A_IzBsKh@{gBnD
9	S. Parman Street	x~oDoyncRzDB|A^fBl@jCpCzAn@~@?zSw@rj@oBdTqA
10	Pemuda Street	f{xD{socRuYjBgFPkB?gOn@

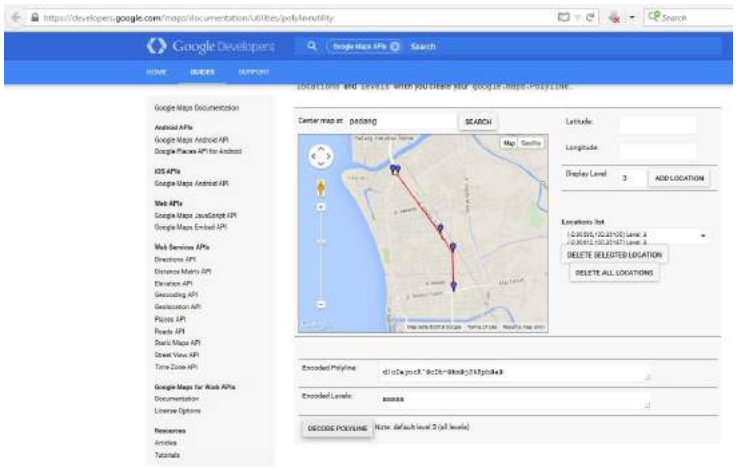

Figure 1. One result of the encoding for one road section

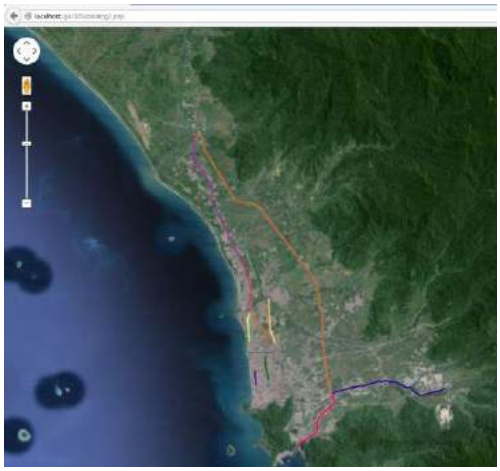

Figure 2. Overall map view for all roads with Google-Maps

The overall result of the encoding process that is integrated to all the roads were then shown on Google-Maps. Figure 2 shows the overall map of all roads and Figure 3 shows the information regarding the selected roads.

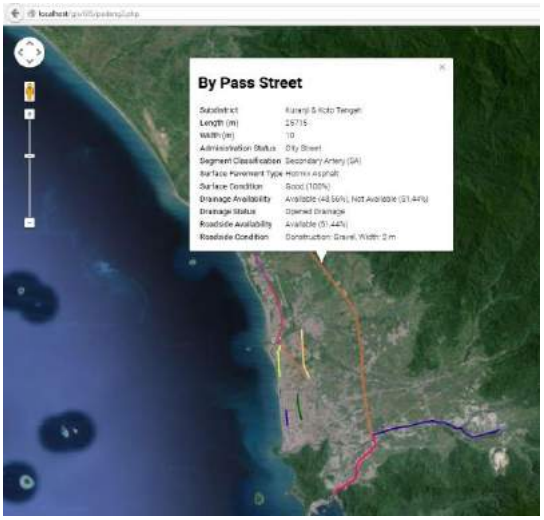

Figure 3. Information on a road section

Conclusion

Road infrastructure management requires very detailed information to carry out its main function to realize excellent road infrastructure. Currently, GIS is used extensively to manage those information. This study has successfully designed a GIS prototype for road infrastructure in West Sumatera were modeled with ten major roads in Padang City. Google-Maps API application used for this modeling and information needed can be found quickly. This information will be useful as a guideline for the stakeholders in the road infrastructure in West Sumatra as well as Padang City to take appropriate action in order to optimize the road performances. Although the information was considered valuable, these applications still need to be refined to the stage of Web-GIS implementation so that the information is real-time and up-to-date.

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